To HIT a

MARK,

As well upon

Ascents and Descents,

As upon the

Plain of the Horizon:

Experimentally and *Mathematically*

DEMONSTRATED.

BY

ROBERT ANDERSON.

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To the Right Honorable

Sir *Henry Goodrick*, Knt and Baront,

Lieutenant General of their MAJESTIES Ordnance,

And

One of His MAJESTIES Moſt Honorable Privy-Council,

AND

To the Honorable

JOHN CHARLETON, Eſq;

Maſter-Surveyor of Their MAJESTIES Ordnance,

AND ALSO,

To the reſt of the *Principal Officers* of the ſame:

This New Work

Is Humbly Dedicated

By

Your moſt Obſervant,

ROB. ANDERSON.

To all Ingenious Persons that delight in the

TRUE USE OF Great Artillery.

IN the Year 1673. *I publish'd my* Genuine Use of the Gun, viz. *To strike a Mark at demand, within the reach of the Piece Analytically, upon the Principles of* Galileus. *In the Year 75. Monsieur* Blondell *propounded that Problem to the* Royal Academy *of Sciences of* France *to be resolved Geometrically, Monsr.* Buot, Romer *the* Sweed, *and Monsieur* de la Hire *set upon the Mathematical part, whilst Monsieur* Mariote *and* Perrault, *with others, imployed themselves about Experiments of several sorts, yet not of the Gun, which is the chief end of that Problem,* Monsigneur *the* Dauphin *being present.*

In the Year 86. Mr. Halley, *in Transaction* Number 179. *gives a Resolution of the same Problem.*

All these purely Mathematical, without the consideration of any Accidental Impediments.

Galileus *tells us the beginning of the Parabola will be deformed, by reason of the Impulse of Fire: And the latter end, by reason of the Resistance of the Air, which amounts to very little, saith he.*

Cavalierus *bids us begin the Parabola where the Force leaves the thing projected. And this Line I call the Line of Impulse of Fire, and take it for a right Line for ease of Calculation; although I believe the thing projected moves as it can so far as the Impulse of Fire, or violent*

shake

ſhake of the Engin is upon it, and the more irregular the thing projected is, the longer the Line will be before it paſſeth into its Parabola.

In theſe laſt 15 *Years I have made more than a Thouſand Experiments (and am ready to make as many more to illuſtrate theſe Truths) altho I ſet down ſo few; by which I find the Impulſe of Fire, and ſo carry the Work on upon the Principles of* Galileus, viz. *To hit a Mark not only upon the Plain of the Horizon, but upon Aſcents and Deſcents in the Parabola, according to Mathematical Principles. For eaſe of the Mortar-Piece, I have made a Table of Horizontal Ranges, and the like may be done for Aſcents and Deſcents, if it were neceſſary; Alſo, by the Experiments of Mr.* Eldred *and my own compar'd together, I have made Tables of Ranges for Long Guns to* 8 *degrees of Elevation, which I am apt to believe comes near the matter; that ſo when proved and approved, the ſaid Ranges may be graved upon the Guns; ſo their Uſe will become very eaſie and exact. Who ever go about to prove or diſprove theſe things, I would have them qualified with theſe three Qualifications,* viz. Art, Care, *and* Honeſty, *and not to ſtand a tip-toe to ſee farther than Nature and Art have made them capable. To make the Work more perfect, I have given a ſhort Diſcourſe of* Granadoes, Fuſees, Carcaſſes, *and* Fire-Balls. *The ſervice of War being ended, we turn our Guns into Pipes of* Muſick, *playing the Charms of a Soldiers delight, in Conſorts of* Muſical *Inſtruments, where* Sound *and* Time *are actually employed.*

Laſt of all, Guns in Geometrical Proportion, beautiful in ſhape, and delightful in ſound, which might delight the Minds of noble Souls. Theſe things I have done for the Truth, *which has been my* Recreation, *and at my own Charge, and now may be uſeful, if faithfully put in practice, which I am apt to believe will not be corrected in this Age, nor perhaps in the next.*

In the Mortar-Piece, I verily believe, there cannot be three Minutes got; nor in the Long Guns ten, perhaps not five Minutes, taking every thing in its right ſenſe, which I ſhall ever endeavour to do, whilſt

I am

R. A.

ON THE
Moſt Ingenious AUTHOR,
Mr. ROB. ANDERSON, *and his New Work.*

AMongſt the ſeveral Parts of Mathematical Elements, the Sections of a *Cone*, and *Algebra*, have ever been accounted the moſt abſtruſe and curious: But the adapting theſe to explicate the Theories of heavy Bodies forc'd from Engins, and the like, is that wherein the Age preceding ours, exceeded all that went before it, by the almoſt immenſe and univerſal Wit of *Galileus*: His Scholar *Torricellio* ſucceeded him, and with moſt admirable Felicity and Learning render'd thoſe matters eaſie, which his Maſter had made Mathematical. But, *To hit a Mark (within the Pieces reach) in any Angle above or under the Horizontal level of the Piece*, was what they could not overcome. And *Torricellius* does profeſſedly avow the Difficulties thereof to be almoſt inſuperable.

But *this*, our Author, by his extraordinary Abilities in Mathematicks, happy Addreſs, and indefatigable Pains and Diligence, has not only overcome, but further added many uſeful things, to render this *New Science* profitable.

Thoſe who have written on this Subject ſince the Author's Printing of his *Genuine Uſe of the Gun, &c.* 1673. have all *confirm'd* what he firſt publiſh'd to the World. Nor can this Doctrin meet with any Oppoſition, except from thoſe who neither underſtand the *Laws* of Motion, nor the *Nature* of that Line wherein a Bullet moves.

His

His long and great Experince (having in Twenty Years made many Thouſand Shots, with greater Accuracy each, perhaps, than *Men of common Practice* ever have made one); his great Curioſity, Expence, and Labor; of all which this preſent Piece of his is an undoubted Inſtance; but moſt of all his Zeal to benefit the Publick, without regard of profiting himſelf, renders him meritorious, not only of the Thanks and Praiſes of his Friends, but as he truly is an Honor to our Age and Nation, the ſame is due to him from all Mankind. The matter of this preſent Tract being wholly new, it could not reach that Length at which Collectors aim, who write the Hiſtories (as I may ſay, the Life and Death) of ſuch or ſuch a Science: But it truly ſeems to be all that was wanting to complete the Art.

Now having its Foundation laid in Scientifique Certitude, confirm'd by much and long Experience, and thus explain'd by Numbers; it neither needs nor can have greater Commendation, other than reading of the Book it ſelf, from which I ſhall no longer keep you.

B. M.

TO Hit a MARK.

Proposition I.

GALILEUS *Dialogo Quarto*, Prop. 1. *Projectum dum fertur motu compoſito ex horizontali æquabili, & ex naturaliter accelerato deorſum, lineam Semiparabolicam deſcribit in ſua latione.*

If a thing be projected in a Motion compounded of an equal Horizontal, and naturally accelerated motion downward, it deſcribeth in its paſſage a Semiparabolical Line.

And from Page 180 to 190, Diſcourſes of the Accidental Impediments, *viz.* Of the Roundneſs of the Earth; The Impediment of the Air; and The Impulſe of Fire. Here I ſhall endeavour to enquire what the Quality and Quantity of theſe accidental Impediments are.

Prop. II.

EXperiments made with a Mortar-piece well fixed, the Diameter 4 Inches, the length of the Chaſe 2 Diameters, the Chaſe and Ball turned very fit.

On *Wimbleton-Heath, Auguſt* 24. 1676.

½ at 15 deg. of Elevation	Ranged the Shot	1336 1378	1357
¾ at 75 deg. of Elevation	Ranged the Shot	1232 1442	1337
½ at 10 deg. of Elevation	Ranged the Shot	539 537	538
¾ at 80 deg. of Elevation	Ranged the Shot	514 500	507

Septemb. 17. 1677.

1 at 15 deg. of Elevat.	Ranged the Shot	901
2 at 75 deg. of Elevat.	Ranged the Shot	848
3 at 00 deg. of Elevat.	Ranged the Shot	125
The Shot fell lower than the Centre of the Mouth of the Piece		235

Lo Specchio uſtorio, **Bonaventura Cavalieri,** Pag. 99.

Dico adunque, che I gravi ſpinti dal proiciente à qualſivoglia banda, fuorche per la perpendicolare all' Orizonte, ſeparati che ſiano da quello, & eſcluſa l'impedimento dell' ambiente, deſcrivono una linea curva, inſenſibilinente differente dalla Parabola.

I ſay then, that heavy Bodies being projected by any force, except it be perpendicular to the Horizon, and excluding the Impediment of the Medium, do after their ſeparation from that force deſcribe a curve Line inſenſibly differing from a Parabola.

Prop. III. Prob. I.

TWO Ranges made upon the plain of the Horizon, equi-diſtant above and below 45 deg. of Elevation, with the ſame Piece, Ball, and quantity of Powder being given. To find the Line of impulſe of Fire, and greateſt Range in the Parabola.

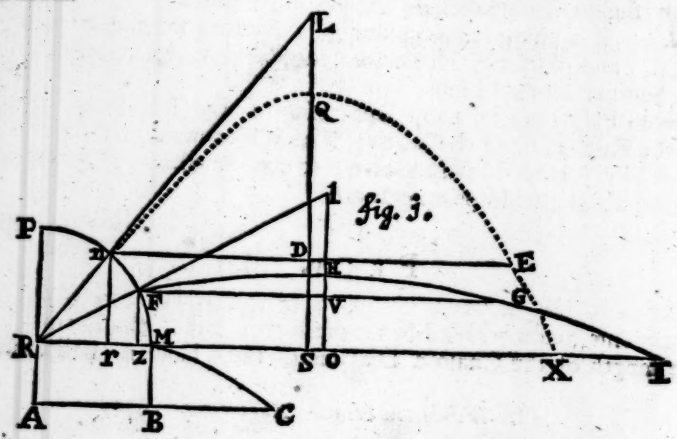


fig. 3.

Let R be the Axis on which the Piece moves, in *Fig.* 1.

The Range RI at 15 deg. of Elevation	901 the half 450.5	=B
The Range RX at 75 deg. of Elevat.	848 the half 424	=C
The ſine of the Angle RFZ		=S
The ſine of the Angle R *nr*		=∫
The Line of Impulſe of Fire RF	the thing ſought	=Z

Then as Radius : Z :: S : RZ in the Diag. that is $\frac{ZS}{R}$ = RZ in Diag. and $\frac{Z\int}{R}$ = R*r* in the Diag. then $B-\frac{ZS}{R}=C-\frac{Z\int}{R}$, *Galilem Dialog. quart. Prop. oct.* that is, $RB-ZS=RC-Z\int$, that is $\frac{+RB}{-RC}=\frac{-Z\int}{+ZS}$, that is,

Half

Half the difference of the Ranges multiplied by Radius, divided by the difference of the ſine Complement of Elevations, the Quote is the Radius RF=Z the thing ſought, the Line of Impulſe of Fire.

Here we take RO to be equal to OI, which is not exactly ſo; yet nevertheleſs it is ſufficient for the purpoſe.

Example.

½ The difference of the Ranges in Radius	2650000	6.423246
The difference of the ſines of 15 and 75 deg.	70711 ſub	4.849487
The Radius of the Circle RF=Z the Line of Impulſe of Fire	37.48	1.573759

To find the greateſt Range in the Parabola.

As the Radius		90	10.000000
is to the ſine of		15	9.412996
ſo is the Radius	RF	37.48	1.573759
to	Rr	9.7	0.986755
As the Radius		90	10.000000
is to the ſine of		75.	9.984944
ſo is the Radius	RF	37.48	1.573759
to	RZ	36.2	1.558703

½ the Range on the Horiz. at 75°		424	½ the Range on the Horizon at 15°		450.5
Rr	ſub	9.7	RZ	ſubſt.	36.2
ND		414.3	FV		414.3
The Range at 75° NE, in Parab.		828.6	equ. to the Ran. FG at 15° in Parab.		828.6

Then the double of NE or FG 1657.2 the greateſt Rang in the Parabola.

PROP. IV. PROB. II.

THE Piece put parallel to the Horizon at R, Ranged the ſhot RMC, that is, the horizontal diſtance AC, the deſcent RA equal to MB, with the Range at 15 deg. of Elevation upon the plain of the Horizon RI being given. To find RM the Line of Impulſe of Fire.

The Range RI at 15 deg. of Elevat.	901 the half	450.5=B
The Piece put parallel to the Horizon Ranged the ſhot	125	AC=A
RA the height of the Piece above where the ſhot fell	2.35	=C
The ſine of the Angle RFZ		=S
Radius		=R
RM=AB the Line of impulſe of Fire, the thing ſought		=Z

Then $\frac{ZS}{R}=RZ$ in the Diag. B$-\frac{ZS}{R}$ FV in the Diag. Then A$-$Z its ſquare $A^2-2AZ+Z^2$, that ſquare divided by 8C is $\frac{A^2-2AZ+Z^2}{8C}=FV$ in Diagr. ſo then $\frac{A^2-2AZ+Z^2}{8C}=\frac{BR-ZS}{R}$, that is $RA^2-2RAZ+RZ^2=8CBR-8CSZ$, that is, $RZ^2=\frac{+2RAZ+8CBR}{-8CSZ-A^2R}$. In Numbers thus, $Z^2=231.84$ $Z=7155.6$ its ſquare Root is $36.67=Z=RF$ the Line of Impulſe.

Here note, if $A^2-2AZ+Z^2$ be divided by C, the Quote will be the double of the greateſt Range in the Parabola; if by 2C the greateſt Range, if by 4C the half of the greateſt Range, if by 8C a quarter of the greateſt Range in the Parabola FV.

Prop. V. Prob. III.

THE horizontal diſtance, and the deſcent being given. To find the double of the greateſt Range in the Parabola.

BM, 2.35. AC, 125 leſs AB, 36.67. Their remains BC, 88.33 being given. To find the greateſt Range in the parabola.

BC	88.33		1.946108
		ſquared	3.892216
BM	2.35	ſub	0.371068
The double of the greateſt Range which we call G	3320		3.521148
The half thereof is	1660	the greateſt Range.	

Prop. VI. Prob. IV.

THE horizontal diſtance, the deſcent, and the double of the greateſt Range in the Parabola being given. To find the Line of impulſe of Fire.

AC		125=A
RA equal to MB		2.35=C
G the double of the greateſt Range	3320	being given.

To find RM the Line of impulſe=Z.

Then A$-$Z, ſquared is $A^2-2AZ+Z^2=GC$, that is, $Z^2=2AZ\frac{+GC}{-A^2}$

In Numbers thus $Z^2=250Z-7823$. Whoſe ſquare Root is $36.68=Z=RF$ the Line of Impulſe.

A method to extract the Roots of ſquare Equations.

Take half the number of the coefficient. To the ſquare of that half, add or ſubſtract the abſolute number, according to the Sign + or $-$, then extract the ſquare

ſquare Root of that ſum or difference, which Root added to or ſubſtracted from the half coefficient, the ſum or difference will be the Root of the Equation.

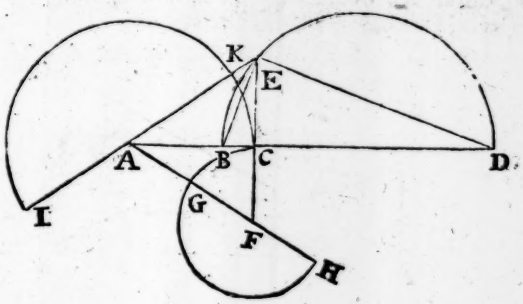
Example.

Take half of 250 (which is called the Coefficient) 125 its ſquare is 15625 from that ſquare ſubſtract the abſolute Number 7823 by the ſign —, the remainder is 7802, the Root thereof 88.32, ſubſtracted from 125 the remainder is 36.68 the Root required.

In theſe Experiments at 0 degree of Elevation, and at 15 deg. of Elevation there could be very little reſiſtance of the Medium; therefore it is the impulſe of Fire carrying the Ball in a right line, ſo far as the blaſt of the Piece is upon it, which after its ſeparation from that force, paſſeth into the Curve of a Parabola.

By this means the point N is removed from the point F, which is one, if not the chief reaſon, that RX and RI are not equal upon the plain of the Horizon.

PROP. VII. PROB. V.



THE three laſt Propoſitions, *viz.* the 4th. 5th. and 6th. may be done Geometrically. Thus, if (in the 4th.) BC in the Diagr. be made equal to 8C in the equation, and CD in the Diag. be equal to B in the equation, then CE is a mean proportion. If EA in the Diag. be equal to A in the equation, and AF in the Diag. be equal to half the Coefficient in the equation, then HA and GA will be the Roots of the equation, and GA equal to 36.67.

If we take mean proportions between 2A and R, and 8C and S in the Coefficient part of the equation, the conſtruction will be more compleated.

In the 5th.

If BC in the Diagr. be made equal to BM in the 5th. Prop. and CE in the Diagr. be equal to BC in the 5th. Prop. Then CD in the Diagr. a 3d. proportion will be equal to G the double of the greateſt Range in the Parabola.

In the 6th.

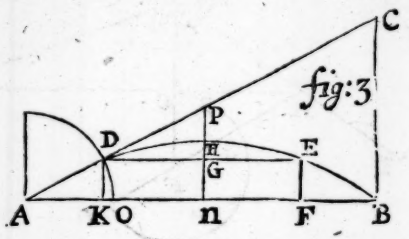
If BC in the Diagr. be made equal to C in the equation, and CD in the Diag. be equal to G in the equation, then CE is a mean proportion, make EA in the Diag. equal to A in the equation, then IE, and KE are the Roots of the equation, and KE=36.67.

Prop. VIII. Prob. VI.

IF two ſhot be made at the ſame degree of elevation, with different quantities of Powder, the correſponding parts of the Ranges will be in proportion, ſufficiently near the truth. And to find the parts ſimile.

June the 5th. 1677. On *Wimbleton-Heath*, a Mortar-piece whoſe diameter of bore 4 inches, and the length of the Chaſe 2 diameters, charged with 4 ounces of Powder, and laid to 15 deg. of elevation, Ranged its ſhot to the horizontal diſtance of 659 paces.

By this, and what is done by the Experiments before cited, the qualifications of all Mortar-pieces are known, being of the ſame kind.



Example.

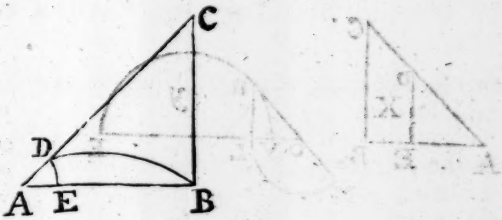
As RI	*fig.* 1.	the Range at 15 deg. of elevation	901	2.954725
is to RF		the Line of impulſe	37.48	1.573759
ſo is AB	*fig.* 3.	the Range at 15 deg. of elevation	659	2.818885
to AD		the Line of impulſe	27.41	1.437919

As RI	*fig.* 1.	the Rang. at 15 deg. of elevat. 901 on the Hor.	2.954725
is to FG		the Rang. at 15 deg. of elevat. 828.6 in the Parab.	2.918345
ſo is AB	*fig.* 3.	the Rang. at 15 deg. of elevat. 659 on the Horiz.	2.818885
to DE		the Rang. at 15 deg. of elevat. 606 in the Parab.	2.782505

DE 606 the Range at 15 deg. of elevat. in the Parabola, the double of it is 1212 Paces the greateſt Range at 45 deg. of elevat. in the Parabola.

PROP. IX. PROB. VII.

THE Line of impulse, the greatest Range in the Parabola, and the Angle of elevation being given. To find the Range upon the plain of the Horizon.



In the right angled Triangle ABC, there is given the Angle BAC, AD the line of impulse, and G the double of the greatest Range in the Parabola, with this qualification, as G:DC::DC:CB. To find AB the horizontal Range.

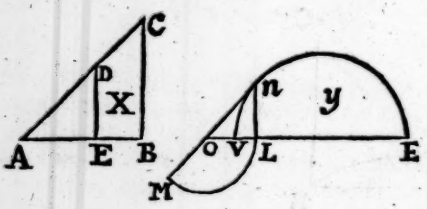
BAC=S	sine 70	93969
R	=	100000
G	=	2424
AD	=r	27.41
DC=Z		230489

Then, as $R:r+Z::S:BC$ in diag. that is $\frac{rS+ZS}{R}=BC$ in diag. and $\frac{Z^2}{G}=BC$ in diag. by Lemma to the 23 Prop. *De motu projectorum Liber Secundus, Torricel.* Therefore $\frac{Z^2}{G}=\frac{rS+ZS}{R}$ That is $Z^2R=ZGS+GrS$. In Numbers thus, $Z^2=2277.80856Z+62434.7326296$, the Root is $2304.89=DC$. Then

DC 230489+DA27.41=AC	2332.3	3.3677847
sine	70	9.5340525
AB	797.69	2.901836

A Second way by Lines thus, Geometrically.

In Fig. X. If A C be made Radius, and C B the ſine of the Angle of elevation, and A D the Line of impulſe, draw D E parallel to C B, then DE will be a fourth proportion by 12. 6 *Euclid.* Then make VL in *Fig.* Y. equal to DE in *Fig.* X, and L E in *Fig.* Y, equal to the double of the greateſt Range; the Line LN will be a mean proportion, 13. 6. *Euclid.* Further, if AC in *Fig.* X. be made Radius, and C B the ſine of the Angle of elevation, and AD the greateſt Range from the point D draw DE parallel to BC, DE will be a fourth proportion; Laſtly, make OL in *Fig.* Y. equal to DE in *Fig.* X. then draw the Line NOM, and it will be the Line required, *viz.*=Z in the equation, and DC in the firſt *Fig.* of this Propoſition.



A Third way by Logarithms.

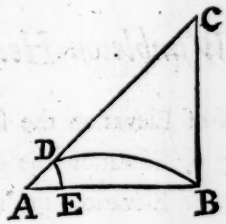
G= 2424	3.384533	G= 2424	3.384533
S= 93969	4.972985	S =93969	4.972985
r= 27.41	1.437709		8.357518 from
	9.795427 from	2R=200000	5.301030 ſubſt.
R=100000	5.000000 ſubſt.	OL 1138.9	3.056488 ſubſt.
	4.795427 reſt	LN+Radius	12.397713 from
LN =	2.397713 half	LON tang. 12.22.30	9.341225 reſt
		LON ſine 12.22.30	9.331041 ſubſt.
		LN+Radius	12.397713 from
		ON 1165.9	3.066672 reſt
		LO+ON 2304.8	*viz.* =Z in the

Equation, and DC in the firſt *Fig.* of this Propoſition.

A *Fourth Way* ſhall be ſhewed, where we come to calculate the horizontal Ranges.

PROP. X. PROB. VIII.

THE Horizontal distance, the Line of Impulse, the double of the greatest Range in the Parabola being given. To find the Angle of Elevation, to hit an Object at the Horizontal distance given.



In the Right angled triangle ABC, AB the Horizontal distance, AD the Line of Impulse, the Line G the double of the greatest Range, with this qualification, as G:DC::DC:CB being given. To find the Angle BAC, the angle of Elevation, to hit the Object at B, at the Horizontal distance AB.

AB=H= 264
G = 568.867
AD=r 6.534

To find the Roots { Z= 487.3= DC Paces.
Z= 302.8= DC

Then $\frac{Z^2}{G}$=CB in the Diagr. $r+Z$=AC in Diagr. squared is $r^2+2rZ+Z^2$ $=H^2+\frac{Z^4}{G^2}$ 47 *I. Euclid.* that is $Z^4=G^2Z^2+2rG^2Z+r^2G^2$ $-H^2G^2$

That Equation in Numbers.

$-Z^4+323609.663689Z^2+4228931.085087852Z=2254048320 2.613561987516$

The Roots are had, by the usual method of extracting mixt Powers, which will be very easie to any ingenious Person, with a little practice; the lesser Root is greater than EB, and lesser than DC at 45 deg. of Elevation. The greater Root DC, is greater than DC at 45 deg. of Elevation, and lesser than DC, at the Complement of the lower Elevation from the Zenith.

DC	302.8	DC	487.3
AD	6.534	AD	6.534
AC	309.334	AC	493.834

C

As

As AC	309.33	2.490422
is to the Radius	90	10.000000
ſo is AB	264	2.421604
to the ſine of the angle BAC	31° 24′ 30″	9.931182
As AC	493.83	2.490422
is to the Radius	90	10.000000
ſo is AB	264	2.421604
to the ſine of the angle BAC	57° 41′	9.728027

On *Wimbleton-Heath*,

1689. *June* 17.	1. at 10 deg. of Elevation the ſhot Ranged	610
	2. at 78. 56 of Elevation the ſhot Ranged	616
	3. at 15 deg. of Elevation the ſhot Ranged	680
	4. at 73 . 57 of Elevation the ſhot Ranged	724
Auguſt 13.	1. at 15 deg. of Elevation the ſhot Ranged	694
	2. at 15 deg. of Elevation the ſhot Ranged	680
	3. at 73 . 57 of Elevation the ſhot Ranged	711
	4. at 73 . 57 of Elevation the ſhot Ranged	682
	1. at 31 . 24 of Elevation the ſhot Ranged	1953
	2. at 31 . 24 of Elevation the ſhot Ranged	1932
	3. at 57 . 41 of Elevation the ſhot Ranged	1975
	4. at 57 . 41 of Elevation the ſhot Ranged	2020
	1. at 31 . 24 of Elevation the ſhot Ranged	1077
	2. at 31 . 24 of Elevation the ſhot Ranged	1105
	3. at 57 . 41 of Elevation the ſhot Ranged	1077
	4. at 57 . 41 of Elevation the ſhot Ranged	1135

Here note, *If the Horizontal diſtance be greater than the greateſt Range of the Piece; the Object is beyond the reach of the Piece.*

On

On *Wimbleton-Heath*, June 26. 1689.

1. at 15 deg. of Elevation the ſhot Ranged	1149	
2. at 15 deg. of Elevation the ſhot Ranged	1197	—1173
3. at 75 deg. of Elevation the ſhot Ranged	1104	
4. at 75 deg. of Elevation the ſhot Ranged	1102	—1103

In *Fig.* I.

½ the difference of the Ranges in Radi 3500000	6.544068
the difference of the Sines of 15 and 75 deg 70711 ſubſt.	4.849487
the Radius of the Circle RF the line of Impulſe 49.5	1.694581

As the Radi		90	10.000000
is to the ſine of		15°	9.412996
ſo is the Radi	RF	49.5	1.694581
to	Rr	12.8	1.107577

As the Radi		90	10.000000
is to the ſine of		75°	9.984944
ſo is the Radi	RF	49.5	1.694581
to	RZ	47.8	1.679525

½ the Rang. on the Hor. at 75°		551.5	½ the Rang. on the Horiz. at 15°		586.5
	Rr ſubſt.	12.8		RZ ſubſt.	47.8
	ND	538.7		FV	538.7
the Ran: at 75° NE in the Par.		1077.4	equ. to the Ran. FG at 15° in Par.		1077.4

As RI is to RF *Fig.* I	the Range at 15 deg. of Elevation	901	2.954725
	the Line of Impulſe	37.48	1.573759
In this Experiment	the Range at 15 deg. of Elevation	1173	3.069298
	the Line of Impulſe	48.8	1.688332

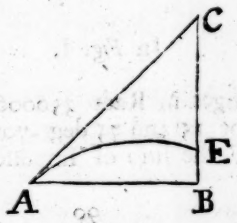
Here may be ſeen, the fair agreement of the Parabola, with Experiments:

For 49.5 leſs 48.8 is but ſeven Tenths.

Upon *Aſcents* and *Deſcents*.

Prop. XI. Prob. IX.

THE angle of Elevation, the double of the greateſt Range, the Aſcent or Deſcent being given. To find the Horizontal diſtance.



In the right angled Triangle ABC, the Angle BAC, the double of the greateſt Range G, and the Aſcent BE, with this qualification; as G:AC::AC:CE being given: To find AC=Z.

Then, as R:Z::S:BC in Diagr. that is $\frac{ZS}{R}$=BC in Diagr. Then $\frac{ZS-PR}{R}$=CE in Diag. Then $\frac{Z^2}{G}$=EC in Diag. that is $Z^2R=ZGS-GPR$.

	G=	2424
	BE=P=	120
the ſine of	80=S=	98481
	Radius=R=	100000
	AC=Z=	2258.37

In *Numbers* thus,

$Z^2=2387.17944Z-290880$ whoſe Roots are 2258.37=AC=Z, and 128.8=AC=Z.

By

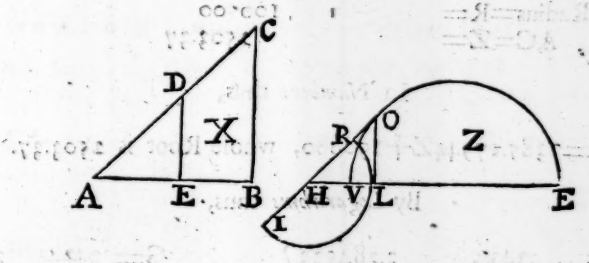
By *Logarithms* thus,

G= 2424	3.384533	G= 2424	3.384533	
P= 120	2.079181	S= 98481	4.993352	
	½ 5.463714		8.377885	from
LO+Radius is	12.731857	2R= 200000	5.301030	subst.
		HO= 1193.6	3.076855	subst.
		LO+Radius	12.731857	from
		fine LHO	9.655002	rest
		co-fine LOH	9.950405	
		HO= 1193.6	3.076855	
		HL= 1064.8	3.027260	
		HO+HL = 2258.4=AC=Z		
		HO−HL = 128.8=AC=Z		

Radius		10.000000
AC	2258.4	3.353801
BCA fine 10°		9.239670
AB	392.17	2.593471

AB the Horizontal distance.

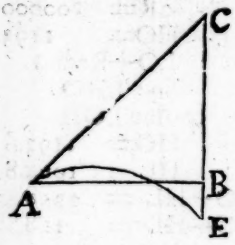
By *Lines* thus,



In *Fig.* Z, if VL be made equal to P, and LE equal to G, then LO will be a mean Proportion. Further, in *Fig.* X, if AC be made equal to Radius, and BC equal to the fine of the Angle of Elevation; as alſo, AD be made equal to ½ G, that is equal to the greateſt Range in the Parabola, then DE will be a fourth Proportion. Further, from the point O in *Fig.* Z, make OH equal to DE in *Fig.* X, continue the Line OH to I. Laſtly, ſet one point of the Compaſſes in H, and at the diſtance HL, ſweep the Arch ILR, then are IO and RO the Lines required.

Prop. XII. Prob. X.

THE Angle of Elevation, the double of the greateſt Range, and the Deſcent being given. To find the Horizontal diſtance.



In the right angled Triangle ABC, the Angle BAC, the double of the greateſt Range G, and the deſcent BE, with this qualification as G : AC :: AC : CE being given. To find AC = Z.

Then, as R : Z :: S : BC in Diagram that is $\frac{ZS}{R}$ = BC in Diagr. Then $\frac{ZS+PR}{R}$ = CE in Diag. Then $\frac{Z^2}{G}$ = EC in Diagr. that is $Z^2R = ZGS + GPR$.

	G =	2424
	BE = P =	120
The ſine of 80 =	S =	98481
	Radius = R =	100000
	AC = Z =	2503.37

In *Numbers* thus,

$Z^2 = 2387.17944Z + 290880$, whoſe Root is 2503.37.

By *Logarithms* thus,

G =	2424	3.384533 }		G = 2424	3.384533 }
S =	98481	4.993352 }		P = 120	2.079181 }
		8.377885	from		½ 5.463714
2R =	200000	5.301030	ſubſt.	LO + Radi. is	12.731857
HL =	1193.6	3.076855	ſubſt.		
LO + Radius		12.731857 }	from		
LHO Tang.	24.19	9.655002 }			
LHO Sine	24.19	9.614665 }	ſubſt.		
HO =	1309.8	3.117192			
HL + HO		2503.4 = AC the Number deſired.			

Radi

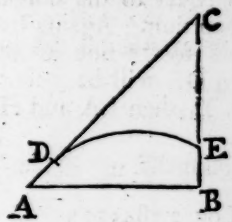
Radi	90	10.000000
AC	2503.4	3.398530
BCA fine	10	9.239670
AB	4347	2.638200 AB the Horizontal diſtance.

By *Lines* thus.

In *Fig.* X and Z, if VL be made equal to P, and LE equal to G, then LO will be a mean Proportion. Further, in *Fig.* X, if AC be made equal to Radius, and CB equal to the ſine of the Angle of Elevation; as alſo, AD be be made equal to $\frac{1}{2}$G then DE will be a fourth Proportion. Again make LH in *Fig.* Z, equal to DE in *Fig.* X, draw the Line OHI, ſet one foot of the Compaſſes in H, and at the diſtance HL ſtrike the Arch LI, then IO will be the Line required.

PROP. XIII. PROB. XI.

THE Line of Impulſe, the double of the greateſt Range in the Parabola, the Aſcent or Deſcent, and the Angle of Elevation being given. To find the Horizontal diſtance.



In the right angled Triangle ABC, the Angle BAC, the double of the greateſt Range G, the Line of Impulſe AB, and the perpendicular Aſcent BE, with this qualification, as G : DC :: DC : DE, being given. To find DC=Z.

Then $R : r+Z :: S : BC$, that is $\frac{rS+ZS}{R}=BC$ in Diag. $\frac{Z^2}{G}=CE$ in Diagr. then $\frac{Z^2+PG}{G}=BC$ in Diag. that is $\frac{Z^2+PG}{G}=\frac{ZS+rS}{R}$ *i.e.* $Z^2R=ZGS+GrS-GPR$

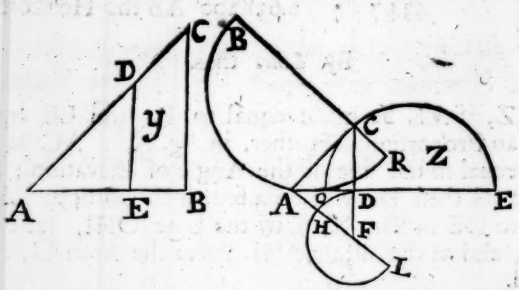
G=	2424
BE=P=	120
AD=r=	2741
ſine of 80=S=	98481
Radius=R=	100000
DC=Z=	2288.67

In *Numbers*, thus,

$Z^2=2387.17944Z-225447.4115496$ whoſe Roots are 2288.67 and 98.51.

By

By *Lines* thus,



Upon an Aſcent. In *Fig.* Y, if AC be made Radius, and CB the ſine of the Angle of Elevation, and AD the Line of impulſe, and DE drawn parallel to CB, then DE will be a fourth Proportion. In *Fig.* Z, if OD be made equal to DE in *Fig.* Y, and DE in *Fig.* Z be made equal to the double of the greateſt Range in the Parabola, then DC will be a mean Proportion. Further, if RC be made equal to P the perpendicular Aſcent, and CB equal to the double of the greateſt Range, then CA will be a mean Proportion. Again, in *Fig.* Y, if AC be made equal to the Radius, and CB equal to the ſine of the angle of Elevation, and AD the greateſt Range, then DE will be a fourth Proportion, make AE in *Fig.* Z, equal to DE in *Fig.* Y, then LA and HA are the Lines deſired.

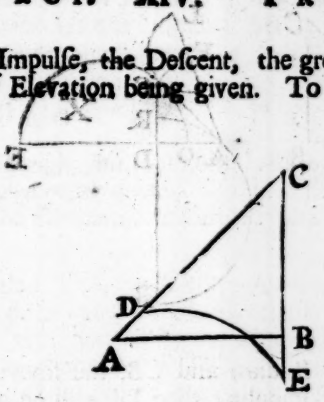
By *Logarithms* thus,

G	Log.	3.384533	G	Log.	3.384533	G Log.	3.384533
r		1.437909	S		4.993352	P	2.079181
S		4.993352			8.377885	½	5.463714
		9.815794	2R		5 301030	AC is	2.731857 ſubſt.
R	ſub.	5.000000	AF	1193.6	3.076855	DC+Ra.	12.407897 from
		4.815794					9.676040 ſi. of DAC
DC		2.407897 ½					9.944661 ſi. of DCA
	Laſtly.					AC	2.731857
AD		27.41				AD from	12.676518
DC		2288.7				AF ſubſt.	3.076855 1193.6
AC		2316.1			3.364757	reſt	9.599663 ſi. of AFD
ABC		10 ſine.			9.239670	add AF	9.962590 ſi. of DAF
AB		402.2			2.604427		3 039445 1095.1
the Horizontal diſtance deſired.						AL the Number	2288.7de.

PROP.

Prop. XIV. Prob. XII.

THE Line of Impulſe, the Deſcent, the greateſt Range in the Parabola; the Angle of Elevation being given. To find the Horizontal diſtance.



In the right angled Triangle ABC, the Angle BAC, AD the Line of Impulſe, and G the double of the greateſt Range in the Parabola being given, with this qualification G:DC::DC:CE. To find AB the Horizontal diſtance.

Then $R:r+Z::S:BC$ that is $\frac{rS+ZS}{R}BC$ in Diagr. $\frac{Z^2}{G}=CE$ in Diagram.

Then $\frac{Z^2+PG}{G}=BC$ in Diagr. that is $\frac{Z^2-PG}{G}=\frac{rS+ZS}{R}$ that is

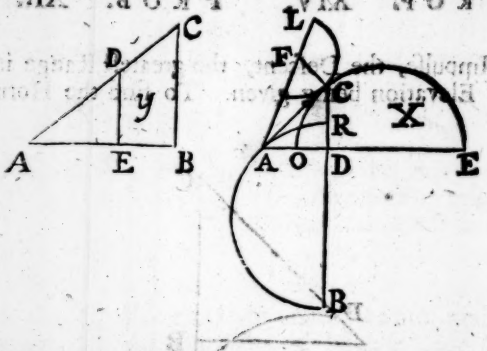
$Z^2R=ZGS+GrS.$
$+GPR.$

	$G=$	2424
$BE=P=$		120
the Sine of $80=S=$		98481
Radius$=R=$		100000
$AD=r=$		27.41
$DC=Z=$		2528.11

In *Numbers* thus,

$Z^2=2387.17944Z+356312.5884504$ the Root is 2528,11.

By *Lines* thus,



In *Fig.* Y, if AC be made Radius, and CB, the ſine of the Angle of Elevation; and AD the Line of impulſe; then DE will be a fourth Proportion. In *Fig.* X. If OD be made equal to DE in *Fig.* Y, and DE in *Fig.* X, be made equal to the double of the greateſt Range, then DC will be a mean Proportion. In *Fig.* X, if DR be equal to the Deſcent, and DB equal to the double of the greateſt Range, DA will be a mean proportion. Then draw the Line AC. Further, in *Fig.* Y. If AC be Radius, and DC the ſine of the Angle of Elevation, and AD the greateſt Range, then DE will be a fourth proportion. In *Fig.* X, draw CF (at right Angle to AC) equal to DE in *Fig.* Y, then ſet one point of the Compaſſes in the point F, and take the diſtance FC, ſweep the Arch CL, then LA will be the Line deſired.

By *Logarithms* thus,

G Log.	3.384533	G Log.	3.384533	G Log.	3.384533
S	4993352	S	4993352	P	2.079181
r	1.437909		8.377885		½ 5.463714
	9.815794	2R ſub.	5.301030	DA	is 2.731857
R ſubſt.	5.000000	CF 1193.6	3.076855		
DC	½ 4.815794				

DC+Radi.	is 12.407897	ſubſt.
DA	2.731857	ſubſt.
Tang. DAC	9.676040	
ſine DAC	9.631992	ſubſt.
DC+Radi.	12.407897	from
AC	2.775905	ſubſt.
FC+Radi.	13.676855	from
Tang. CAF	10.300950	
ſine CAF	9.951528	ſubſt.
AF 1334.5	3.125322	
CF 1193.6		
AL 2528.1	the Numb. deſired.	

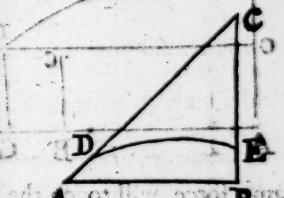
AD	27.41	
DC	2528.1	
AC	2555.5	3.407476
ACB ſine	10	9.239670
AB	443.8	2.647146

Aſcents.

Aſcents.	*Deſcents.*
AB 402.2 with the Line of Impulſe.	AB 443.8 with the Line of Impulſe.
AB 392.2 without the Line of Impul.	AB 434.7 without the Line of Imp:
10.0 the Horizontal difference.	9.1 the Horizontal difference.

PROP. XV. PROB. XIII.

THE greateſt Range, the Horizontal diſtance, Perpendicular Aſcent, and Line of Impulſe being given. To find the Angle of Elevation; to hit the ſaid Aſcent at the Horizontal diſtance given.



In the right angled Triangle ABC: the double of the greateſt Range in the Parabola G, the Horizontal diſtance AB, the Aſcent BE, the Line of Impulſe AD, with this qualification G:DC::DC:CE, being given. To find the Angle BAC.

Then $\frac{Z^2}{G}=CE$ in Diag. Further, $\frac{Z^2+PG}{G}=CB$ in Diagr. that ſquared is $\frac{Z^4+2Z^2PG+P^2G^2}{G^2}$ that $+H^2$ is equal to the ſquare of $r+Z$, that is $r^2+2Zr+Z^2$.

that is $\frac{Z^4+2Z^2PG+P^2G^2}{G^2}+H^2=r^2+2Zr+Z^2$. 47. I. *Euclid.* that is

$$Z^4+2PGZ^2-2rG^2Z=r^2G^2-G^2Z^2-H^2G^2-P^2G^2$$

	$G=$	2424
$AB=H=$		392.2
$BE=P=$		120
$AD=R=$		27.41
Radius$=R=$		100000
$DC=Z=$		2290.6

In *Numbers* thus,

$Z^4-5294016Z^2-3221100040.32Z=-9840134572692544$

Whoſe Root is 2290.6=DC for the upper Elevation.

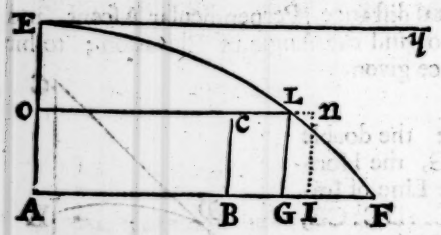
Then,

DC	2290.6		
AD	27.41		
AC	2318.01	ſubſt.	3.365113
Radius	90		10.000000
AB	392.17		2.593474
Co-ſine of the Angle ACB	80° 15′ 40″		9.228361

The Angle of Elevation to hit the Object at E.

Prop. XVI. Prob. XIV.

THE double of the greateſt Range in the Parabola, the Horizontal diſtance, the Perpendicular Aſcent or Deſcent being given. To find whether the Object be within the Reach of the Piece or not.



The double of the greateſt Range EY, the Horizontal Diſtance AB, the Perpendicular Aſcent BC being given. To find whether the Object C be within the Reach of the Piece or not. Let AF be the greateſt Range, AE half thereof, Let ELF be a Semi-Parabola, then all the Projections from the Point A made with the ſame force will touch the Parabola ELF. *Toricel. de Mot. Proj. lib. 2. Prop. 30.*

Then EY equal to 2AF, or 4AE in EO equal to the ſquare of OL. *Appol. Coni. Lib. 1. Prop. 11.* Therefore if the Horizontal Diſtance AG be equal to OL, it is in the fartheſt extent of the Projection; if it be leſs as AB, the Point C is within; but if greater, as AI, the Point N is without, therefore beyond the Reach of the Piece, that is, if half the greateſt Range, leſs the Altitude of the Object in Aſcents, more in Deſcents, be multiplyed by the Parameter (equal to the double of the greateſt Range) whoſe ſquare Root, if leſs than the Horizontal diſtance, the Object is out of the Reach of the Piece.

AB =	392.17	OE =	486	2.686636
EY =	2424	EY =	2424	3.384533
AF =	1212		=	6.071169
AE =	606	OL =	1085.4	3.035584
AO =	120			

AB = 392.17 leſs than OL = 1085.4 therefore the Object at C is within the Reach of the Piece.

If any find the XV. Propoſition tedious, they may make uſe of the Tables in my genuine Uſe of the Gun; for the difference is not much, as appears in the Cloſe of the XIV. Propoſition; the difference is 10 in the Aſcent and 9 in the Deſcent, in that place; and in the XV. Propoſition it is 16 minutes.

By the Tables in my genuine Uſe of the Gun.

Greateſt Rang.	G	1212	ſub. 3.083503	greateſt Range	G	1212	ſub. 3.083593
Greateſt Rang.	G	2000	3.301030	greateſt Range	G	2000	3.301030
Horizont. diſt.	H	392.17	2.593474	Perpend. Aſcent	P	120	2.079181
Horizont. diſt.	H	647.15	2.811001	Perpend. Aſcent	P	198	2.296708

Then entering the Tables with the Horizontal diſtance 647.15 and Perpendicular Aſcent 198, and you will find the Elevations 80 deg. and 27. deg.

Thus

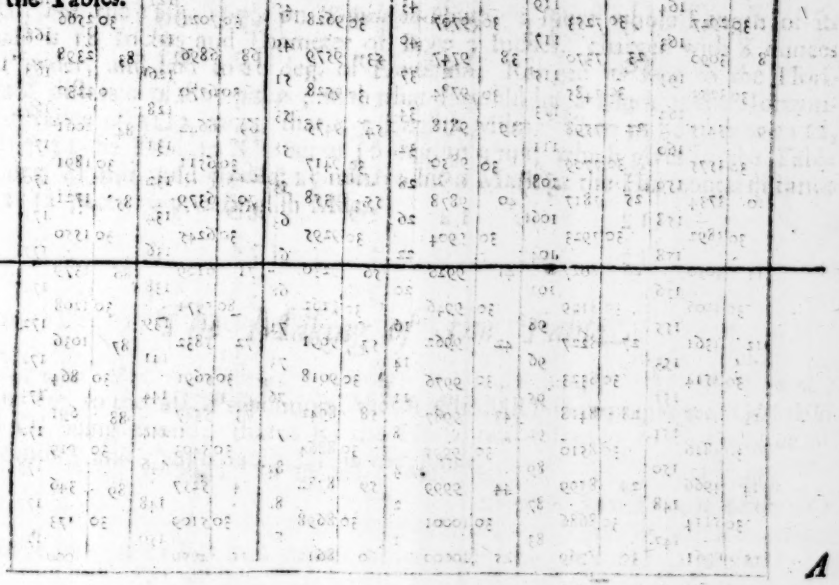
Thus have I given a Method to ſtrike any place at demand within the Reach of the Peice, as well upon Aſcents and Deſcents, as upon the plain of the Horizon, by Experimental and Mathematical demonſtration. It remains now to ſay ſomething of *Mortar-Pieces, Granadaes, Fuſees, Bombs, Carcaſſes,* and *Fire-Balls,* &c.

About 70 or 80 degrees of Elevation is the beſt place to work a Mortar-Piece for ſervice: Therefore I have given Rules from the Elevation given, to find the Horizontal diſtance, which is as neceſſary as the Converſe. Theſe Examples are of both kinds, *viz.* as well upon Deſcents as Aſcents: As alſo, with the Line of Impulſe and without it, that the difference may be ſeen: But this is to be ſure, that, with the Line of Impulſe, will come neareſt the Mark.

In theſe Examples I have made uſe of the Aſcent of *Edinburgh* Caſtle, which is the higheſt Aſcent, if below, or loweſt Deſcent if above, of any Garriſon in this part of the World.

If Mortar-Pieces were all *ſimilis*, and their requiſits of Powder as the Cube of the Diameter of their Bores, and their Granadoes, Bombs, Carcaſſes, and Fire-Balls were *ſimilis*, as they ought to be, their Ranges upon the plain of the Horizon under the ſame deg. of Elevation would be equal, comparing like with like: So one Piece being well proved, that is, the Range of the Granada, Bomb, Carcaſe, and Fire-Ball being found to any degree of Elevation, the whole Work of a Mortar-Piece would become very eaſie and exact.

Conſidering they are not *ſimilis*, there is required the Range of the Piece, at any convenient deg. of Elevation, with its requiſite of Powder, then proceed by the Tables.



A Table of Horizontal-Distances.

de.mi	nu.	dif.	de.mi	nu.	dif.	de.mi.	nu.	dif.	de.mi.	nu.	dif.	de.mi.	nu.	dif.	de.mi.	nu.	dif.
		521			145			82			4			89			151
30	521		30	5406		30	8851		30	9996		30	8523		30	4808	
		521			144			81			5			90			152
1	1042		1	5550		1	8932		31	9989		31	8433		31	4656	
		521			142			80			6			91			154
30	1563		30	5692		30	9012		30	9983		30	8342		30	4502	
		522			142			79			7			92			155
2	2085		2	5834		2	9091		32	9976		32	8250		32	4347	
		523			140			78			8			93			156
30	2608		30	5974		30	9169		33	9968		33	8157		33	4191	
		524			138			77			9			94			157
3	3132		3	6112		3	9246		34	9959		34	8063		34	4034	
		525			137			76			10			95			158
30	3657		30	6249		30	9322		35	9949		35	7968		35	3876	
		526			135			75			11			96			159
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		527			133			74			12			97			160
30	4710		30	6517		30	9471		37	9926		37	7775		37	3557	
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		529			129			72			14			99			162
30	5767		30	6778		30	9616		39	9899		39	7578		39	3234	
		530			128			71			15			100			163
6	6297		6	6906		6	9687		40	9884		40	7478		40	3071	
		531			126			70			16			101			164
30	6828		30	7032		30	9757		41	9868		41	7377		41	2907	
		532			125			69			17			102			165
7	7360		7	7157		7	9826		42	9851		42	7275		42	2742	
		533			123			68			18			103			166
30	7893		30	7280		30	9894		43	9833		43	7172		43	2576	
		534			121			67			19			104			167
8	8427		8	7401		8	9961		44	9814		44	7068		44	2409	
		535			120			66			20			105			168
30	8962		30	7521		30	10027		45	9794		45	6963		45	2241	
		536			118			65			21			106			169
9	9498		9	7639		9	10092		46	9773		46	6857		46	2072	
		537			116			64			22			107			170
30	10035		30	7755		30	10156		47	9751		47	6750		47	1902	
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		539			113			62			24			109			171
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		541			110			60			26			111			172
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12	12735		12	8312		12	10461		52	9626		52	6200		52	1043	
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30	13278		30	8418		30	10519		53	9598		53	6087		53	870	
		544			104			57			29			114			173
13	13822		13	8522		13	10576		54	9569		54	5973		54	697	
		545			103			56			30			115			173
30	14367		30	8625		30	10632		55	9539		55	5858		55	524	
		546			101			55			31			116			173
14	14913		14	8726		14	10687		56	9508		56	5742		56	351	
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30	15460		30	8825		30	10741		57	9476		57	5625		57	178	
		548			97			53			33			118			173
15	16008		15	8922		15	10794		58	9443		58	5507		58	005	
		549			96			52			34			119			173
30	16557		30	9018		30	10846		59	9409		59	5388		59	178	
		550			94			51			35			120			173
16	17107		16	9112		16	10897		60	9374		60	5268		60	351	
		551			92			50			36			121			173
30	17658		30	9204		30	10947		61	9338		61	5147		61	524	
		552			91			49			37			122			173
17	18210		17	9295		17	10996		62	9301		62	5025		62	697	
		553			89			48			38			123			173
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		554			88			47			39			124			173
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19	20428		19	9642		19	11182		66	9143		66	4527		66	1388	
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30	22102		30	9886		30	11311		69	9014		69	4143		69	1902	
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21	22662		21	9964		21	11352		70	8969		70	4013		70	2072	
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30	23223		30	10041		30	11392		71	8923		71	3882		71	2241	
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22	23785		22	10116		22	11431		72	8876		72	3750		72	2409	
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		564			73			37			49			134			173
23	24912		23	10263		23	11506		74	8779		74	3483		74	2742	
		565			71			36			50			135			173
30	25477		30	10334		30	11542		75	8729		75	3348		75	2907	
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		570			65			31			55			140			173
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		571			63			30			56			141			173
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		574			59			27			59			144			173
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		576			57			25			61			146			173
29	31758		29	11031		29	11872		86	8113		86	1797		86	4656	
		577			56			24			62			147			173
30	32335		30	11087		30	11896		87	8051		87	1650		87	4808	
		578			54			23			63			148			173
30	32913		30	11141		30	11919		88	7988		88	1502		88	4961	
		579			53			22			64			149			173
30	33492		30	11194		30	11941		89	7924		89	1353		89	5114	
		580			52			21			65			150			173
30	34072		30	11246		30	11962		90	7859		90	1203		90	5267	
		581			51			20			66			151			173
30	34653		30	11297		30	11982		91	7793		91	1052		91	5420	
		582			50			19			67			152			173
30	35235		30	11347		30	12001		92	7726		92	900		92	5573	
		583			49			18			68			153			173
30	35818		30	11396		30	12019		93	7658		93	747		93	5726	
		584			48			17			69			154			173
30	36402		30	11444		30	12036		94	7589		94	593		94	5879	
		585			47			16			70			155			173
30	36987		30	11491		30	12052		95	7519		95	438		95	6032	
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30	37573		30	11537		30	12067		96	7448		96	282		96	6185	
		587			45			14			72			157			173
30	38160		30	11582		30	12081		97	7376		97	125		97	6338	
		588			44			13			73			158			173
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		590			42			11			75			160			173
30	39927		30	11711		30	12117		100	7154					100	6797	
		591			41			10			76			161			173
30	40518		30	11752		30	12127		101	7078					101	6950	
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30	41110		30	11792		30	12136		102	7001					102	7103	
		593			39			8			78			163			173
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30	43488		30	11942		30	12162		106	6683					106	7715	
		597			35			4			82			167			173
30	44085		30	11977		30	12166		107	6601					107	7868	
		598			34			3			83			168			173
30	44683		30	12011		30	12169		108	6518					108	8021	
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30	46483		30	12107		30	12172		111	6263					111	8480	
		602			30						87			172			173
30	47085		30	12137					112	6176					112	8633	
		603			29						88			173			173
30	47688		30	12166					113	6088					113	8786	
		604			28						89			174			173
30	48292		30	12194					114	5999					114	8939	
		605			27						90			175			173
30	48897		30	12221					115	5909					115	9092	
		606			26						91			176			173
30	49503		30	12247					116	5818					116	9245	
		607			25						92			177			173
30	50110		30	12272					117	5726					117	9398	
		608			24						93			178			173
30	50718		30	12296					118	5633					118	9551	
		609			23						94			179			173
30	51327		30	12319					119	5539					119	9704	
		610			22						95			180			173
30	51937		30	12341					120	5444					120	9857	
		611			21						96			181			173
30	52548		30	12362					121	5348					121	10010	
		612			20						97			182			173
30	53160		30	12382					122	5251					122	10163	
		613			19						98			183			173
30	53773		30	12401					123	5153					123	10316	
		614			18						99			184			173
30	54387		30	12419					124	5054					124	10469	
		615			17						100			185			173
30	55002		30	12436					125	4954					125	10622	
		616			16						101			186			173
30	55618		30	12452					126	4853					126	10775	
		617			15						102			187			173
30	56235		30	12467					127	4751					127	10928	
		618			14						103			188			173
30	56853		30	12481					128	4648					128	11081	
		619			13						104			189			173
30	57472		30	12494					129	4544					129	11234	
		620			12						105			190			173
30	58092		30	12506					130	4439					130	11387	
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30	58713		30	12517					131	4333					131	11540	
		622			10						107			192			173
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		623			9						108			193			173
30	59958		30	12536					133	4118					133	11846	
		624			8						109			194			173
30	60582		30	12544					134	4009					134	11999	
		625			7						110			195			173
30	61207		30	12551					135	3899					135	12152	
		626			6						111			196			173
30	61833		30	12557					136	3788					136	12305	
		627			5						112			197			173
30	62460		30	12562					137	3676					137	12458	
		628			4						113			198			173
30	63088		30	12566					138	3563					138	12611	
		629			3						114			199			173
30	63717		30	12569					139	3449					139	12764	
		630			2						115			200			173
30	64347		30	12571					140	3334					140	12917	
		631			1						116			201			173
30	64978		30	12572					141	3218					141	13070	
		632			0						117			202			173
30	65610		30	12572					142	3101					142	13223	
		633									118			203			173
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		634									120			205			173
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		635									122			207			173
30	67512										123			208			173
		636									124			209			173
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		637									126			211			173
30	68785										127			212			173
		638									128			213			173
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		639									130			215			173
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		640									132			217			173
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		641									134			219			173
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		642									136			221			173
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		643									138			223			173
30	72628										139			224			173
		644									140			225			173
30	73272										141			226			173
		645									142			227			173
30	73917										143			228			173
		646									144			229			173
30	74563										145			230			173
		647									146			231			173
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		648									148			233			173
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		649									150			235			173
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		650									152			237			173
30	77157										153			238			173
		651									154			239			173
30	77808										155			240			173
		652									156			241			173
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		653									158			243			173
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30	79767										161			246			173
		655									162			247			173
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		656									164			249			173
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		657									166			251			173
30	81735										167			252			173
		658									168			253			173
30	82393										169			254			173
		659									170			255			173
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		660									172			257			173
30	83712										173			258			173
		661									174			259			173
30	84373										175			260			173
		662									176			261			173
30	85035										177			262			173
		663									178			263			173
30	85698										179			264			173
		664									180			265			173
30	86362										181			266			173
		665									182			267			173
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		666									184			269			173
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		675									202			287			173
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		678									208			293			173
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		679									210			295			173
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		680									212			297			173
30	97122										213			298			173
		681									214			299			173
30	97803										215			300			173
		682									216			301			173
30	98485										217			302			173
		683									218			303			173
30	99168										219			304			173
		684									220			305			173
30	99852										221			306			173
		685									222			307			173
30	100537										223			308			173
		686									224			309			173
30	101223										225			310			173
		687									226			311			173
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		688									228			313			173
30	102598										229			314			173
		689									230			315			173
30	103287										231			316			173
		690									232			317			173
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		691									234			319			173
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		692									236			321			173
30	105360										237			322			173
		693									238			323			173
30	106053										239			324			173
		694									240			325			173
30	106747										241			326			173
		695									242			327			173
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		696									244			329			173
30	108138										245			330			173
		697									246			331			173
30	108835										247			332			173
		698									248			333			173
30	109533										249			334			173
		699									250			335			173
30	110232										251			336			173
		700									252			337			173
30	110932										253			338			173
		701									254			339			173
30	111633										255			340			173
		702									256			341			173
30	112335										257			342			173
		703									258			343			173
30	113038										259			344			173
		704									260			345			173
30	113742										261			346			173
		705									262			347			173
30	114447										263			348			173
		706									264			349			173
30	115153										265			350			173
		707									266			351	

The Uſe Table of Horizontal Diſtances.

I. Any degree of Elevation under 45 being given, to find at what degree above 45 will hit the ſame horizontal diſtance; ſuppoſe 12 degrees, I look againſt 12 degrees in the Table, and find 4761, which I look for beyond 45 degrees, and find it againſt 76 deg. 57 min. ſo I conclude, a Piece charged with the ſame quantity of the ſame Powder, and the ſame Ball put to 12 deg. and 76 deg. 57. min. of Elevation, will Range the Shot to the ſame Horizontal diſtance.

Here note, Suppoſe a Piece be charged with 1, 2, 3, and 4 parts of Powder and the ſame Ball, and put to thoſe degrees of Elevation, if the upper and lower Ranges be equal, there is no ſenſible reſiſtance of the Medium.

II. *June* the 5th. 1677. on *Wimbleton Heath* I charged the Mortar Piece with 4 ounces of Powder, and put it to 15 deg. of Elevation, it ranged the Ball to the Horizontal diſtance of 659 paces; with that, I would hit a Mark with the ſame Piece, Ball, and quantity of Powder, at the Horizontal diſtance of a 1000 paces. Then as 659, is to a 1000, ſo is 1261 the Tabular Number of 15 deg. to 7983, which gives in the Table 75 deg. 47 min. and 63 deg. 16 min. to hit a Mark at the Horizontal diſtance of a 1000 paces.

III. *Feb.* the 13th. 16[illegible] on *Wimbleton-Heath*, a Piece whoſe Length of its Chaſe is 18 Inches and Diameter of Bore 3 Inches, charged with 8 ounces of Powder, and laid to 10 deg. of Elevation, Ranged its ſhot to the Horizontal diſtance of 1805 paces; with that I would hit a Mark at the Horizontal diſtance of 2112 paces, that is 2 Engliſh Miles: Then as 805, is to 2112, ſo is 3734 the Tabular Number at 10 deg. to 9797, which gives in the Table 38 deg. 41 min. and 50 deg. 25 min. to hit a Mark at the Horizontal diſtance of 2112 paces, viz. 2 Engliſh Miles.

The Making of the Table.

In *Fig.* to the III. Propoſition, the Angle MRF being given, RZ, FV and OI being found; that is RI the Horizontal diſtance to that degree of Elevation; and then reduced, as in the Table.

A Table of the Requisites of Powder of like Mortar-Pieces, from 6 Inches to 20 Inches Diameter; and they are as the Cubes of the Diameters of their Bores.

In.	Dec.	Pou.	Ou.	In.	Dec.	Pou.	Ou.
A		B		A		B	
6		1	13	13		8	09
6	5	1	01	13	5	9	10
7		1	05	14		10	11½
7	5	1	10	14	5	11	14
8		2	00	15		13	03
8	5	2	06	15	5	14	09
9		2	14	16		16	00
9	5	3	06	16	5	17	09
10		3	14½	17		19	03
10	5	4	08	17	5	20	15
11		5	03	18		22	12½
11	5	5	15	18	5	24	11
12		6	12	19		26	13
12	5	7	10	19	5	28	14
				20		31	04

The Use of the Table.

The Diameter of a Mortar Piece 9 Inches and ½ being given. To find the Requisite of Powder.

Look in Column A, and there find 9 Inches and 5 Tenths, and against it in Column B there is 3 Pound 6 Ounces, its Requisite of Powder.

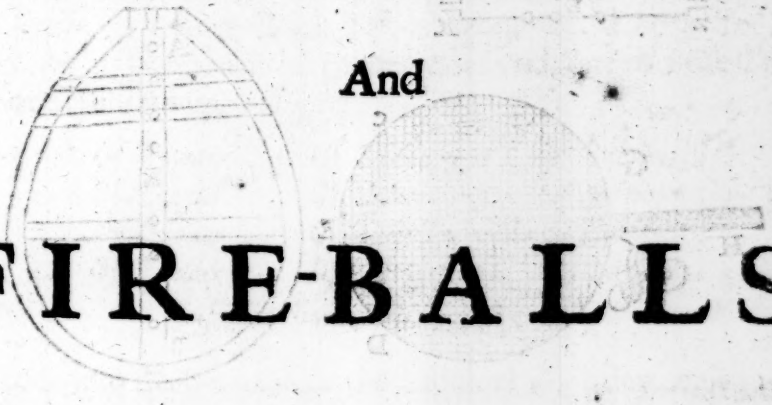
The like in the rest.

OF

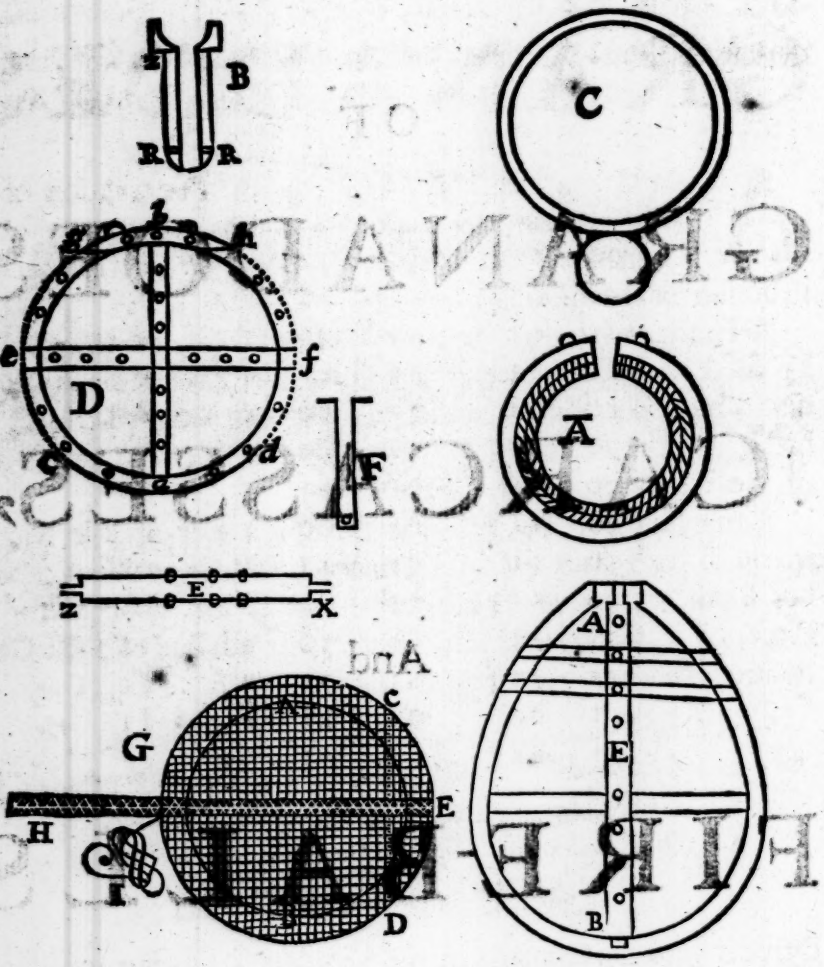
GRANADOES,

CARCASSES,

And



FIRE-BALLS.


B
R
R
C
D
e
f
c
d
F
A
E
Z
X
A
G
C
H
E
I
D
A
E
B

OF

GRANADOES.

AS a Granarium keeps Corn for the Preſervation of the Life of Man, ſo theſe Granariums (corruptly called Granadoes) are filled with Corns of Fire for the Deſtruction of Mankind.

A Granade is a hallow Sphere of Iron (as we may ſo call it) fill'd with Corn-Powder, with a Fuſee to fire the dry Powder to break the Shell when it arrives to the deſigned Object (as in *Fig.* A) the Fuſee B, the Vents R, ZR equal to two Thirds of the Diameter of the Granado.

If the Granado be too little for the Chaſe of the Mortar, marle it with ſlack twiſted Thred, bruſhing it all over with hot Pitch, throwing Brick-duſt thereon, till it be fit for the Piece, by its Gauge C, charge the Fuſees with one of theſe Compoſitions following,

1.	*Of Powder* 1 ℥	*Of Saltpetre* 1 ℥	*Of Sulphur* 1 ℥
2.	*Of Powder* 3 ℥	*Of Saltpetre* 2 ℥	*Of Sulphur* 1 ℥
3.	*Of Powder* 4 ℥	*Of Saltpetre* 3 ℥	*Of Sulphur* 2 ℥
4.	*Of Powder* 4 ℥	*Of Saltpetre* 3 ℥	*Of Sulphur* 1 ℥

Caſimire Simienowiez, Page 206.

Drive it into the Granade to the Shoulder Z, being well glued.

Mortars uſually Range the Granads with their due Requiſit of Powder about 1250 paces upon the plain of the Horizon; the beſt place generally to work a Mortar, is from 70 to 80 deg.

of Elevation, the greateſt Altitude of a Projection at 75 deg. of Elevation whoſe Horizontal diſtance is 1250 paces, is about 583 paces, and the time of the Flight of the Granad will be about 27 Seconds of time, which time the Fuſee ought to continue burning before it fires the Granad; but if upon an Aſcent or Deſcent, leſs or more time is to be allowed, according as the Object is ſituated. And this in the general.

Example.

The greateſt Range in the Parabola		1250	
A ¼ part equal to ND in *Fig.* I		312.5	
In the Right Angled Triangle NDL.			
As Radius		90	10.000000
is to	ND	312.5	2.494850
ſo is Tang. of the Angle	DNL	75	10.571948
to	DL	1166.2	3.066798
the half	DQ	583.1	

Then,

As		20.2 Paces	1.305351
is to the ſquare of 2″. 30‴ that is 150‴ that is		22500	4.352183
ſo is	DQ	583.1	2.765743
to the ſquare of the Time			5.812575
The Root		805.9 *i.e.* 13.43	2.906287
The Double, that is near		27″, 26.86	

To give a Fuſee its juſt time of burning, viz. 27 *Seconds.*

Take a Bullet of any convenient weight, faſten a String to it, meaſure from the Centre of the Bullet, 39 Inces 2 Tenths, make a Loop there, hang it upon a Pin, move the Bullet with your Hand to a convenient diſtance out of its Perpendicularity, then let it looſe, theſe Swings or Vibrations will be Seconds of Time ſufficiently near the truth.

Drive

Drive your Fuſee with one of the former Compoſitions, then fire it, if it continues burning 27 Seconds of Time, you have hit right, if the Fuſee continued not burning the full Time, give it a ſlower Compoſition, or the contrary.

Few Trials make Perfectneſs.

A Bomb has the ſame Office as a Granade, only it is in the form of a Spheriod, that is, longer one way than the other, therefore its Range will be more uncertain.

There are alſo Granads to be caſt with the hand; their Office is the ſame as the former; they are of Iron, Braſs, Glaſs, and other mixt Metals that are brittle.

Thomas Malthus, an Engineer of *England*, was the firſt that exerciſed the Mortar-Piece, and taught the Uſe of Granadoes in the 17 Provinces in *Germany* and *Poland*.

The French King hearing of his good ſucceſs, ſent for him, to inſtruct the French as he had done the Dutch, and imployed him in ſeveral Sieges, and at the Siege of *Graveline*, where he was ſlain by a Muſquet-ſhot in the Head.

William Eldred, 60 Years a Gunner, ſometime Maſter-Gunner of *Dover*-Caſtle, an honeſt induſtrious Perſon, gives us many good Experiments of Long Guns, for the ſpace of thirty Years; a good Work: At the latter end of his days he eat the Charity of charitable *Sutton*, and not the Bounty of his Prince; for he dyed in the *Charter-Houſe*.

OF

CARCASSES.

TAke two Armillas of Iron of a convenient breadth, a little less than the Diameter of the Mortar-Piece to which they belong, put them at right Angles, rivet them fast at each Pole, at *a* and *b* in *Fig.* D.

Rivet a Bason of Iron at the bottom, as *c*, *a* and *d*, to bear the Impulse of Powder and fall of the Carcass, a lesser Bason at the top, as *g b h*, in which there ought to be Holes to fire the Carcass, take an Armilla fit to the Diameter of the Piece, and place it equidistant from each Pole, as *e f*.

Fill it with this Composition.

12 ℥ *of Pitch*
12 ℥ *of Colophone.*
4 ℥ *of Oyl of Turpentine.*
1 ℥ *of Hemp cut short.*

Or,

2 ℔ *of Pitch.*
4 ℥ *of Oyl of Turpentine.*
1 ℥ *of Hemp cut short.*

All these melted together, take fit Marlin, and from the two Shoulders *d* and *c* marle it fast, fill it as you marel, till you come to *g h*, fasten the Marlin to the Armillas with fine Marlin, if need be.

Coat

Coat it with this Receipt.

Pitch	4	℥
Roſin	3	℥
Wax	2	℥
Turpentine	1	℥

Fit it to its Gauge C, make Holes in the top of the Carcaſs about 3 Inches deep, more or leſs, according to the magnitude of the Carcaſs.

Uſe for the Priming the ſame Compoſition as for Fuſees of Granadoes, with quick Match moderately droven into the Holes. If it be deſign'd to place Petards in the Carcaſs, let there be Holes made in the Armillas to fix them in, or they may be placed in the Marlin, as the Carcaſs is a filling: Theſe are things of *Common Senſe*.

There is another kind of Carcaſs, namely, in form of an Egg, as E, whoſe length is a Diameter and half of the Piece to which it belongs, compoſed of two Hoops of Iron and two Baſons, as in the former, with a Zone of Iron in the middle, as alſo a Trunk of Iron E, with two Shoulders, as Z and X, to be placed in the Carcaſs, as A B, with Holes to place the ends of the Petards in, the Trunk filled with a ſlow Compoſition to fire the Petards as the Carcaſs conſumes; theſe Petards, as F, are to be charged with dry Powder and Bullets, to deſtroy thoſe that come to quench the Carcaſs. The Range of this Carcaſs will be very uncertain, by reaſon of the irregular form.

OF-

OF

FIRE-BALLS,

IN *Fig.* G, Take the Trunchion H, wind Marlin about it in form of a Sphere, as AB, leaving the first end of the said Marlin out, as I, about this Sphere of Marlin put Canvas several thicknesses, dipping the Sphere of Marlin in Glue betwixt every thickness of Cloth.

Then coat it with the Coating before cited, till it fits its Gauge C, pluck out the Truncheon H, then draw the Marlin I till it all comes out, there will remain a Concave Sphere A B, which being filled with this Composition, *viz.*

Powder-dust	12	℥
Saltpetre	6	℥
Sulpher	3	℥
Colophone	2	℥ more or less, as necessity requires.

Driving it hard as you fill, it being finished, it's fit for use.

Lastly, place a Bason of Lead at E, as CED, to bear the blast of the Piece, and carry that side of the Ball E foreright, that the mouth of the Ball may be uppermost, when it arrives to its assigned place.

Fill the Concave Sphere AB with either of the Compositions made for the Carcasses, and that will be another sort of Fire-Ball.

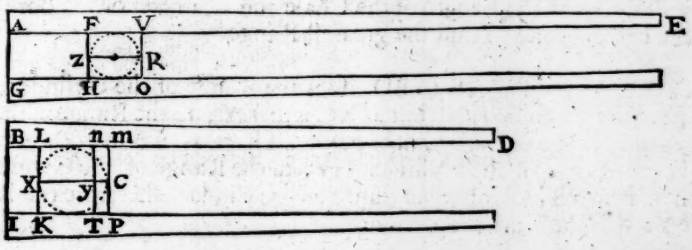
Much more might be said of this Subject, as well as of the whole, but this may suffice at the present.

TO

To HIT a MARK WITH Long Guns.

Proposition I.

THE Length of the Chaſe, Diameter of the Bore, and Requiſite of Powder of any Piece; with the Length of the Chaſe, Diameter of the Bore of any other Piece being given. To find its Requiſite of Powder.



For if, as AE : BD :: AF : BL, thenas the Cylinder GE, is to the Cylinders ID; ſo is the Requiſite of Powder in GF, to the Requiſite of Powder in IL. But as quantity is to quantity, ſo is weight to weight being of the ſame kind. Therefore as the ſquare of AG in AE is to the ſquare of BI in BD; ſo is the weight of the Powder GF, to the weight of Powder in IL. Here we compare the Baſilisk with the Culverin, EAG the Baſilisk, and DBI the Culverin.

L	the Length of the Culverin	11 Foot.	
D	the Diameter of the Bore	5 Inch.	
P	the Requiſite of Powder	9.977	
R	the greateſt Range	4.837	
T	the Time of the Flight of the ſhot.		
F	the comparative Force.		
𝔏	the Length of the Baſilisk	23.5 Foot.	
𝔇	the Diameter of the Bore	4.6 Inch.	
𝔓	the Requiſite of Powder.		
𝔑	the greateſt Range.		
𝔗	the Time of the Flight of the ſhot.		
𝔉	the comparative Force.		

1	the Diameter of the Bore of the Culverin	BI	5 Inches	0.698970
2	the Square of the firſt			1.397940
3	the Length of the Chaſe of the Culverin	BD	11 Foot	1.041393
4	the Log of the ſecond and third			2.439333
5	the Diameter of the Bore of the Baſilisk	AG	4.6	0.662758
6	the Square of the fifth			1.325516
7	the length of the Chaſe of the Baſilisk	AE	23.5	1.371068
8	the Log of the ſixth and ſeventh			2.696584
9	the Requiſite of Powder of the Culverin		9.977	3.998999
10	Log of the 8 and 9			6.695583
11	the Log of the 4 ſubſt.			2.439333
12	the Requiſite of Powder of the Baſilisk	AGFH	18.041	4.256250

That is, $LD^3 : \mathfrak{L}\mathfrak{D}^3 :: P : \mathfrak{P}$, That is, $LD^3\mathfrak{P} = \mathfrak{L}\mathfrak{D}^3P$, ſo any five of theſe ſix being given, the ſixth is alſo given.

1. $LD^3 : \mathfrak{L}\mathfrak{D}^3 :: P : \mathfrak{P}$
2. $D^3\mathfrak{P} : \mathfrak{D}^3P :: \mathfrak{L} : L$
3. $L\mathfrak{P} : \mathfrak{L}P :: \mathfrak{D}^3 : D^3$
4. $\mathfrak{L}\mathfrak{D}^3 : LD^3 :: \mathfrak{P} : P$
5. $\mathfrak{D}P : D^3\mathfrak{P} :: L : \mathfrak{L}$
6. $\mathfrak{L}P : L\mathfrak{P} :: D^3 : \mathfrak{D}^3$

Prop. II.

THE Length of the Chaſe, the Diameter of the Bore and greateſt Range of any Piece, with the Length of the Chaſe and Diameter of the Bore of any other Piece being given, to find the greateſt Range.

Let XY=ZR; then as AE to BD, ſo is the Range of the Cylinder HV, to the Range of the Cylinder KN, but as XC is to XY; ſo the Range of the Cylinder KN to the Range of the Cylinder KM. That is as AE in XC, is to BD in ZR, ſo is the Range of the Cylinder HV, to the Range of the Cylinder KM. But a Sphere is two Thirds of its circumſcribed Cylinder, therefore the Ranges of the Bullets are in the ſame proportion.

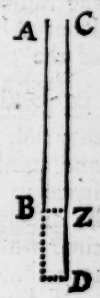
1	the length of the Culverin	BD	11 Foot	1.041393
2	the Diameter of the Bore of the Baſilisk		4.5 Inches	0.662758
3	the Log of the 1 and 2			1.704151
4	the length of the Baſilisk	AE	23.5 Foot	1.371068
5	the Diameter of the Bore of the Culverin	BI	5 Inches	0.698970
6	the Log of the 4 and 5			2.070038
7	the greateſt Range of the Culverin		4837	3.684576
8	the Log of the 6 and 7			5.754614
9	the 3 ſubſt.			1.704151
10	the greateſt Range of the Baſilisk		11.232	4.050463

1. $L\mathfrak{D} : \mathfrak{L}D :: R : \mathfrak{R}$
2. $\mathfrak{D}\mathfrak{R} : DR :: \mathfrak{L} : L$
3. $L\mathfrak{R} : \mathfrak{L}R :: D : \mathfrak{D}$
4. $\mathfrak{L}D : L\mathfrak{D} :: \mathfrak{R} : R$
5. $DR : \mathfrak{D}\mathfrak{R} :: L : \mathfrak{L}$
6. $\mathfrak{L}R : L\mathfrak{R} :: \mathfrak{D} : D$

Prop.

PROP. III.

THE length of the Chase, Diameter of the Bore and force of any Piece; with the length of the Chase, and Diameter of the Bore of any other Piece being given. To find the force.



Let AB be the greatest Range of the Culverin, and CD the greatest Range of the Basilisk. Let the natural falling of the Ball from A to B, be as the Cube of its Diameter, *viz.* 125 the force of the Culverin. The natural falling of the Ball from C to Z be as the Cube of the Diameter of the Ball of the Basilisk 97.336; the falling of the Ball from C to D be the force of the Basilisk, to be found; as the square Root of AB=CZ, is to the square Root of CD so is the force at Z, to the force at D. *Torricel. de Motu Proj. Lib.* II. *Prop.* XXII.

1	the greatest Range of the Culverin	AB	4.837	3.684576
2	the square Root of the 1			1.842288
3	the greatest Range of the Basilisk		11.232	4.050457
4	the square Root of the 3			2.025228
5	the Diameter of the Bore of the Basilisk		4.6	0.662758
6	the Cube of the 5			1.988274
7	the Log of the 4 and 6			4.013502
8	the 2 subst.			1.842288
9	the force of the Basilisk		148	2.171214

1 $L\mathfrak{D} : \mathfrak{L}D :: \mathfrak{D}^6 : \mathfrak{f}^2$ 4 $\mathfrak{L}D : L\mathfrak{D} :: \mathfrak{f}^2 : \mathfrak{D}^6$

2 $\mathfrak{D}\mathfrak{f}^2 : D\mathfrak{D}^6 :: \mathfrak{L} : L$ 5 $D\mathfrak{D}^6 : \mathfrak{D}\mathfrak{f}^2 :: L : \mathfrak{L}$

3 $L\mathfrak{f}^2 : \mathfrak{L}\mathfrak{D}^6 :: D : \mathfrak{D}$ 6 $\mathfrak{L}\mathfrak{D}^6 : L\mathfrak{f}^2 :: \mathfrak{D} : D$

Prop. IV.

THE Length of the Chaſe, Diameter of the Bore of any Piece, with the Time of the flight of the ſhot; with the length of the Chaſe, Diameter of the Bore of any other Piece being given. To find the Time or Duration of the ſhot in its flight.

Let AB be the greateſt Range in the Culverin, CD=AF the greateſt Range of the Baſilisk, the time of the falling of the Ball from A to B, is to the time of the falling of the Ball from A to F; as the ſquare Root of AB, is to the ſquare Root AF. Or as AB to AF, ſo the ſquare of the time of AB, to the ſquare of the time AF. *Torricel. de Motu Proj. Lib.* II. *Prop.* XIX.

June 24. 1686. I made an Experiment of the falling of heavy Bodies from the top of *Cripplegate* Steeple, which is 101 Foot higher than the place where they fell, *viz.* Three Iron Balls, one of 5 Inches Diameter, another of 3 Inches, and another of 2 Inches and an half Diameter, which conſtantly paſſed that ſpace in 2″ 30‴ of Time, with ſuch exactneſs, that not any difference could be diſcerned; Mr. *Leake*, Mr. *Tompion*, our famous Watchmaker, who kept time with a Watch that moved ¼ ſeconds, Mr. *Norris*, Mr. *Morden*, with ſeveral other Perſons there preſent.

If any heavy Body fall 101 foot, or 20.2 paces in 150 thirds of time, what time ſhall it require to fall 4837 paces, the greateſt Range of the Culverin. As 20.2 is to the ſquare of 150, ſo is 4837 to the ſquare of the time.

1	the Time	150 thirds	2.176091
2	the ſquare of the 1		4.352182
3	the greateſt Range of the Culverin	4837	3.684576
4	the Log of the 2 and 3		8.036758
5	the firſt ſpace	20.2 ſubſt.	1.305351
6	the Log of the ſquare of the time		6.731407
7	the time 2321‴, that is, 38″ 41‴		3.365703

The time of the flight of the ſhot of any Piece at 45 degrees of Elevation, is the time of the falling of an heavy Body the greateſt Range of the ſame Piece.

1	the Log of the ſquare of the time of the Culverin		6.731407
2	the greateſt Range of the Baſilisk	11.232	4.050463
3	the Log of the 1 and 2		10.781870
4	the greateſt Range of the Culverin	Log. ſubſt. 4837	3.684576
5	the Log of the ſquare of the time of the Baſilisk		7.097294
6	the time of the Baſilisk 3537‴ that is 58″ 57‴		3.548647

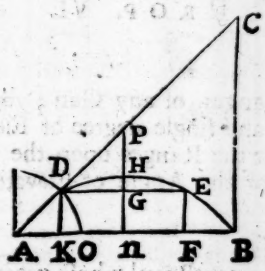
Or,

1	$\mathfrak{L}\mathfrak{D} : \mathfrak{A}\mathfrak{D} :: \mathfrak{T}^2 : \mathfrak{C}^2$	4	$\mathfrak{A}\mathfrak{D} : \mathfrak{L}\mathfrak{D} :: \mathfrak{C}^2 : \mathfrak{T}^2$
2	$\mathfrak{L}\mathfrak{C}^2 : \mathfrak{A}\mathfrak{T}^2 :: \mathfrak{D} : \mathfrak{D}$	5	$\mathfrak{D}\mathfrak{T}^2 : \mathfrak{D}\mathfrak{C}^2 :: \mathfrak{L} : \mathfrak{A}$
3	$\mathfrak{D}\mathfrak{C}^2 : \mathfrak{D}\mathfrak{T}^2 :: \mathfrak{A} : \mathfrak{L}$	6	$\mathfrak{A}\mathfrak{T}^2 : \mathfrak{L}\mathfrak{C}^2 :: \mathfrak{D} : \mathfrak{D}$

Prop.

Prop. V.

THE greateſt Range in the Parabola, the Line of Impulſe, the Angle of Elevation being given. To find the Range upon the plain of the Horizon



The greateſt Range in the Parabola 1657.2 DE, the Line of Impulſe A D, the Angle KAD 45 deg. of Elevation. To find AB the Range upon the plain of the Horizon.

As Rad.		90	10.000000
is to	AD	37.48	1.573800
ſo is the ſine of the Angle	KAD	45 deg.	9.849485
to	KD or AK	26.5	1.423285

DAK being 45 deg. therefore ADK is 45 deg. therefore AK is equal to KD, and by the ſame reaſon, GP and DG are equal, therefore GH is equal to half DG.

HG	414.3	
DK	26.5	
HN	440.8	
As HG	414.3	2.617315
is to HN	440.8	2.644242
ſo is the ſquare of DG or GE	8286	5.836690
to the ſquare of NB		5.863617
ND	854.7	2.931808
NK	828.6	
AK	26.5	
AB	1709.8	

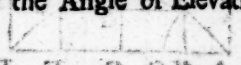
Here note, AK and FB differs but 4 Tenths of a Unit, therefore in the following Work, I take the double of AK for them both.

PROP.

Prop. VI.

To make a Table of Ranges, of any Gun; for the plain of the Horizon to every 30 Minutes and ſingle degree of Elevation.

And here remember, that the Ranges upon the plain of the Horizon, are as the ſines of the double of the Angle of Elevation.



For Example ſake, the Cannon Royal whoſe greateſt Range is 3298 paces.

As	AB	1709.8	3.232945
is to	AD	37.48	1.573800
ſo is the greateſt Range of the Cannon		3298	3.518251
to the Line of Impulſe		72 paces	1.859106

If we make uſe of the laſt Diagram, and ſuppoſe AB to be the Horizontal Range at 45 deg. of Elevation of the Cannon Royal, and AD the Line of Impulſe 72 paces. Then,

As the Rad.		90	10.000000
is to the ſine of the Angle	ADK	45 deg.	9.849485
ſo is the Line of Impulſe	AD	72	1.859106
to	AK	51	1.708591

The greateſt Range of the Cannon Royal AB 3298
ſubſt. FB+AK=102
The greateſt Range in the Parabola DE 3196

As

As the Rad.			90	subst.	10.000000
is to			DE 3196		3.504607
so is the sine of			1 deg.		8.241855
to			56		1.746462
L:P		72	2 deg.		8.542819
		56	112		2.047426
	30	128	3 deg.		8.718800
		112	167		2.223407
1		184	4		8.843585
		167	223		2.348192
	30	239	&c.		
		223			
2		295	&c.		

These Calculations may suffice, till such time as we have more Experiments to confirm these; or to make Tables of Ranges more exactly.

The greatest Ranges of Long Guns, are deduced from many Experiments made by *Eldred* in his Gunners Glass, especially those in Pag. 74. 1611. *July* 2. and Pag. 75. 1636. *August* 30. The manner how they are deduced may be seen in my *Genuine Use of the Gun, Prop.* 1, 2, 3, 4. Printed for *Robert Morden*, at the *Atlas* in *Cornhil*, near the *Royal Exchange*.

These Ranges for single degrees, are deduced from those Ranges, and what was done on *Wimbleton-Heath, Septemb.* 17. 1677.

A Table of the Names, Diameters of the Bores, and Length of the Chaſes of Ten ſeveral Pieces of Canon; with their Requiſites of Powder, greateſt Ranges, Comparative Force, with their Ranges to 8 deg. of Elevation, Experimentally and Mathematically demonſtrated.

The Names of each Piece.		*Lengths of the Chaſes.*	*Diamet. of the Bores.*	*Requiſits of Powder.*	*Greateſt Ranges.*	*Comparative Force.*
		Feet.	*Inches.*	lb ℥	*Paces.*	
A Rabbinet	1	3	1.75	5	3769	38
A Falconet	2	4	2	9	4398	61
A Falcon	3	6	2.75	1 10	4797	166
A Minion	4	8	3	2 10	5864	238
A Saker	5	9	3.5	4	5654	371
A Demi Culverin	6	10	4.5	7 5	4886	733
A Culverin	7	11	5	10	4837	1000
A Demi Cannon	8	11	6	14 6	4031	1575
A Whole Cannon	9	12	7	21 5	3769	2422
A Cannon Royal	10	12	8	27 14	3298	3382

The

The USE *of these Ranges.*

Suppose an Engineer be commanded to batter a Bastion, or a Curtain, at the Horizontal distance of 900 paces, with a whole Cannon, a Demi Cannon, and a Culverin; I look in the Table, and find 900 against the Demi Cannon, and at the head 6°, for the whole Cannon 6° 27′ and for the Culverin 4° 52′ to batter the said Bastion or Curtain, taking the proportional parts; thus, in the Culverin, 80 : 30′ : 60 : 22′, whole Cannon 63 : 30′ : 58 : 27′.

	0°		30′		1°		30′		2°		30′		3°		30′		4°	
	L.P.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.	R.	D.
1	83	64	147	63	210	64	274	64	338	63	401	64	465	63	528	63	591	63
2	96	74	170	75	245	74	219	74	393	74	467	74	541	74	615	74	689	74
3	105	81	186	81	267	81	348	81	429	81	510	81	591	80	671	81	752	80
4	128	99	227	99	326	99	425	93	524	99	623	99	722	98	820	99	919	98
5	124	96	220	95	315	96	411	95	506	95	601	9	697	95	792	94	886	95
6	107	83	190	82	272	83	355	82	437	83	520	82	602	82	644	82	766	82
7	106	83	189	81	270	82	352	81	433	82	515	81	596	82	678	80	758	82
8	88	68	156	68	224	68	292	69	361	68	429	67	496	68	564	68	632	67
9	83	64	147	63	210	64	274	54	338	69	401	64	465	63	528	63	591	63
10	72	56	128	56	184	55	239	56	295	56	351	55	406	55	461	56	517	55

Here note well also; The Object that the Ball is to hit, ought to be as high above the Horizon, as the Mouth of the Piece; if not, the Ranges at 0, 1, 2, and 3 degrees of Elevation will sensibly differ, those Ranges at 6, 7, and 8 degrees of Elevation not so much as the former.

	30'		45'		0°		15'		30'		45'		1°		15'		30'	
	R.	D.	R.	D.	R.	D.	R.	D.	R.	D	R.	D.	R.	D.	R.	D.	R.	
1	654	3	717	63	780	62	842	63	905	62	967	61	1028	62	1090			
2	763	73	836	73	909	73	982	72	1055	72	1127	72	1199	72	1271			
3	832	80	912	80	992	79	1071	80	1151	78	1229	79	1308	78	1386			
4	1017	98	1115	97	1212	97	1309	97	1406	97	1503	96	1599	95	1694			
5	981	94	1075	94	1169	94	1263	93	1356	93	1449	93	1542	92	1634			
6	848	81	929	81	1010	81	1091	81	1172	80	1252	80	1332	80	1412			
7	840	80	920	81	1001	79	1080	81	1161	79	1240	80	1320	78	1398			
8	699	67	766	67	833	67	900	67	967	66	1033	66	1099	65	1165			
9	654	63	717	63	780	62	842	63	905	62	967	61	1028	62	1090			
10	572	55	627	55	682	54	736	55	791	54	845	54	899	54	953			

Warlike

Warlike Musick

ILLUSTRATED,

In several Consorts of Phrygian *Flutes.*

Clearly demonstrated by Principles of

Musick and Mathematicks.

PROP. I.

THE length of the Chase 12 foot of a Cannon Royal being given. To find the length of the Chases of seven lesser Pieces of Cannon that shall be in Musical Proportion.

The greater tone	$\frac{9}{8}$	their Log.	95424251
			90308999
The difference of their Log.			5115252
The lesser tone	$\frac{10}{9}$	their Log.	10000000
			95424251
The difference of their Log.			4575749
The half Note	$\frac{16}{15}$	their Log.	1.20411998
			1.17609126
The difference of their Log.			2801872

The perfect Eight	$\frac{2}{1}$	12	1.07918125	
			4575749	$\frac{12}{9}$
The middle Seventh	$\frac{9}{5}$	10.8	1.03342376	
			5115252	$\frac{9}{8}$
The leſſer Sixth	$\frac{8}{5}$	9.6	0.98227124	
			2802872	$\frac{16}{15}$
The perfect Fifth	$\frac{3}{2}$	9	0.95424252	
			5115252	$\frac{9}{8}$
The perfect Fourth	$\frac{4}{3}$	8	0.90309000	
			4575749	$\frac{10}{9}$
The leſſer Third	$\frac{6}{5}$	7.2	0.85733251	
			2802872	$\frac{16}{15}$
The greater Second	$\frac{9}{8}$	6.75	0.81930379	
			5115252	$\frac{9}{8}$
The Uniſound	$\frac{1}{1}$	6	0.77815127	

PROP. II.

THE Diameter of the Bore of the Cannon Royal *being* 8 *Inches. To find the Diameter of the Bore of ſeven leſſer Pieces of Cannon, which ſhall be in Muſical Proportion: By the firſt.*

PROP. III.

THE Requiſite of Powder of the Cannon Royal being 28 *Pounds. To find the Requiſite of Powder of ſeven leſſer Pieces of Cannon in Muſical Proprortion:* By the firſt.

PROP. IV.

THE Force of the Cannon Royal being taken to be as the Cube of the Diameter of the Bore, viz. 512. *To find the Force of ſeven leſſer Pieces of Cannon which ſhall be in Muſical Proportion:* By the firſt.

PROP. V.

THE Time of the Flight of the ſhot of the Cannon Royal 1000. *To find the time of the flight of the ſhot of ſeven leſſer Pieces of Cannon which ſhall be in Muſical Proportion:* By the firſt.

PROP. VI.

THE Length of the Chaſe, Diameter of the Bore of the Cannon Royal, as alſo the Length of the Chaſe, and Force of any of the aforeſaid Pieces being given. To find the Diameter of its Bore.

PROP.

Prop. VII.

THE Length of the Chase, Diameter of the Bore, and the Time of the Flight of the shot of the Cannon Royal, as also the Length of the Chase, and time of any of the aforesaid Pieces being given. To find the Diameter of its Bore.

Prop. VIII.

THE Length of the Chase 12 *Foot, the Diameter of the Bore* 8 *Inches, the Requisite of Powder* 28 lb *of a Cannon Royal being given. To find the Length of the Chase, Diameter of the Bore, and Requisite of Powder of seven lesser Pieces of Cannon, which shall be in Geometrical Proportion.*

The Length of the Chase	12 Foot		Log.	1.07918125
Its half	6 Foot		Log.	0.77815127
The difference of the			Log.	30102998
The 7th. part is, add				4300428
Add to the length of the least		1	6 foot	0.77815127
		2	6.624	0.82115555
		3	7.314	0.86415983
		4	8.076	0.90718411
		5	8.916	0.95016839
		6	9.844	0.99317267
		7	10.869	1.03617655
		8	12.	1.07918123

The like for the Diameters.

The Requisite of Powder	28 lb		Log.	1.44715803
The eighth part thereof is	3.5		Log.	0.54406804
The difference of the			Log.	0.90308999
The 7th part is				0.12901285
		1	3.5	0.54406804
		2	4.71	0.67308089
		3	6.34	0.80209374
		4	8.53	0.93110659
		5	11.48	1.06011944
		6	15.46	1.18913229
		7	20.80	1.31814514
		8	28.	1.44715809

I. By the first Proposition for the length of the Chase, and second Proposition for the Diameter of the Bore; we compose the first Consort of *Phrygian* Flutes, whose visible shapes are in Musical Proportion, the Ranges and Time upon the same degree of Elevation are equal, their Force and Requisite of Powder as the Cube of the Diameters of their Bore.

II. By the first Proposition for the Length of the Chase, and third Proposition of the Requisite of Powder, we compose the second sort of *Phrygian* Flutes, whose Sounds or Reports and Ranges shall be in Musical Proportion, the Diameter of their Bores equal.

III. By the first Proposition for the Length of the Chase, and the fourth Proposition for the Force, and Proposition the 5th. for the Diameter of the Bore, we compose a third sort of *Phrygian* Flutes whose Force shall be in Musical Proportion.

IV. By the first Proposition for the Length of the Chase, and 6th. Proposition for the Time of the Flight of the shot, and Proposition the 7th. for the Diameter of the Bore, we compose a fourth sort of Warlike Flutes, whose Times shall be in Musical Proportion.

V. By the eighth Proposition we find the Length of the Chase, Diameter of the Bore, Requisite of Powder of Eight Pieces of Cannon in Geometrical Proportion, their Ranges upon the same degree of Elevation equal.

So then, here is nothing wanting in these things that the Heart of Man can in reason desire; for in the first, the Eye is satisfied, their shapes are in Musical Proportion. In the second, the sense of Hearing is delighted, their Sounds are in Musical Proportion. In the third the sense of Feeling may be terrified, the Smart of the Blow in Musical Proportion. In the fourth, that precious thing called Time is employed in delightful Musical Proportion.

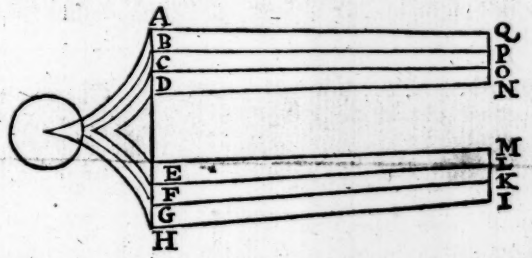
What can be presented to a Prince more delightful, or what can a Prince more delight in, than to conquer his Enemies with Musick and Delight?

From

FRom what has or may be ſaid concerning Guns in *Muſical* and *Geometrical* Proportion, and what may be ſaid concerning Guns under other Qualifications, it may manifeſtly appear, that the buſineſs of *Gun-founding* lyes as open for Improvements in theſe days, as their Uſes did when *Galileus* firſt appeared in the World: For,

An Engineer draws the Draught of a Gun, and gives it a certain Fortification, the Founder founds it according to the Draught or Pattern, a Proof-Maſter proves it, and gives it its Requiſite of Powder. *Quere*, Whether it be the *Engineer*'s or *Draught-Man*'s buſineſs to give it its Requiſite of Powder, and conſequently its Range, or the *Proof-Maſter*'s?

Then,



I. *In the Diagram, Let* K, G, B, *and* P, *be any Piece of Cannon. It being demanded to increaſe the Mettal to* I, H, A, *and* Q; *or decreaſe the Mettal to* L, F, C, *and* O; *ſo as the ſtrength of the Mettal* K, G, B, *and* P, *be to the ſtrength of the Mettal* I, H, A, *and* Q, *as* 3 *to* 7; *and to* L, F, C, *and* O, *(being of the ſame Mettal) as* 7 *to* 3.

The Requiſite of Powder, and Range at 45 degrees of Elevation of the Piece I, H, A, and Q; and the Piece L, F, C, and O, are required.

II. *If the Lengths of the Chaſes of two Pieces, and the Diameters of the Bores of the ſame two Pieces be as* 8 *to* 9. ~~*To give them ſuch Mettal that the ſtrength of one Piece may be to the ſtrength of the other, as* 3 *to* 7.~~

Their Requiſites of Powder and greateſt Ranges are required.

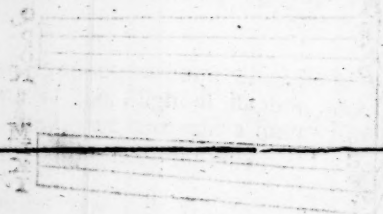
III. *If the Lengths of the Chaſes of two Pieces be as* 9 *to* 10, *and the Diameters of their Bores be as* 4 *to* 5. *To give them ſuch Mettal, that their ſtrengths may be as* 3 *to* 7.

Their Requiſites of Powder, and greateſt Ranges are required.

To

To Conclude.

HERE I might produce a Jury of Mathematicians, famous for their Learning, for the confirmation of that of the *Parabola*: But it is so evident in it self, that he that is ignorant of, and denies that, *viz.* The Flight of the Bullet to be in the Curve of a *Parabola*, deserves not the *Name* of a Mathematician, Philosopher, Engineer, or Fire-Master, no, not of a private Gunner.



FINIS.